# CHAPTER ONE

## :Introduction 1.1

Nuclear medicine is a branch of medical imaging that uses small amounts of radioactive material to diagnose and determine the severity of or treat a variety of diseases, including many types of cancers, heart disease, gastrointestinal endocrine, neurological .disorders and other abnormalities within the body

Because nuclear medicine procedures are able to pinpoint molecular activity within the body, they offer the potential to identify disease in its earliest stages as well as a patient's .immediate response to therapeutic intervention

Nuclear medicine imaging procedures are noninvasive and, with the exception of Intravenous injections, are usually painless medical tests that help physicians diagnose and evaluate medical .conditions

These imaging scans use radioactive materials .calledradiopharmaceuticals or radiotracers

Depending on the type of nuclear medicine exam, the radiotracer is either injected into the body, swallowed or inhaled as a gas and eventually accumulates in the organ or area of the body being .(examined.**(**www.radiology

Radioactive emissions from the radiotracer are detected by a special camera or imaging device that produces pictures and .provides molecular information

In many centers, nuclear medicine images can be superimposed with computed tomography (CT) or magnetic resonance imaging(MRI) to produce special views, a practice known as image fusion or registration. These views allow the information from two different exams to be correlated and interpreted on one image, leading to more precise information and accurate diagnoses. In addition, manufacturers are now making single photon emission computed tomography/computed tomography (SPECT/CT) and positron emission tomography/computed tomography (PET/CT) units that are able to perform both imaging exams at the same time. An emerging imaging technology, but .not readily available at this time is PET/M

Nuclear medicine also offers therapeutic procedures, such as radioactive iodine (I-131) therapy that use small amounts of radioactive material to treat cancer and other medical conditions affecting the thyroid gland, as well as treatments for other cancers and medical conditions. Non-Hodgkin's lymphoma patients who do not respond to chemotherapy may undergo radio immune therapy (RIT). Radio immunotherapy (RIT) is a personalized cancer treatment that combines radiation therapy with the targeting ability of Immunotherapy, a treatment that mimics cellular activity in the body's immune system. .((www.radiology

## :Problem of study .2

Evaluation the room design for SPECT Gamma Camera is not .conducted in Sudan to the best of the researcher's knowledge

## :Importance of study .3

This is the first research in this topic in Sudan and could be used as reference for SPECT room design in the future in Sudan as .general

## :Objectives of study .4

### :General objective 4.1

Toevaluate the room design for SPECT Gamma Camera in Alnilain-

.and RICK for nuclear medicine centers

### :Specific objectives 4.2

To assess the room design for SPECT gammaCamera in Alnilain-

.and RICK for nuclear medicine centers

To measure all the room's dimensions, including walls, ceilings, -floors in the Radiation and Isotopes Center of Khartoum and .Alnailin Centers

To calculate the doses received by workers in nuclear medicine -department and make sure that radiation dose to workers is .within the range of the national and international standards

To determine the annual doses of workers of the two centers-

.under study

**:study outlines-5**

:This study consists of the following

Chapter one: deals with introduction, Problem, Importance of

.study, andobjectives

.Chapter two: literature review

.Chapter three: materials and methods

.Chapter four: deals with results and discussion

.Chapter five: conclusion and recommendations

References

Appendices

# CHAPTER TWO

# Literature Review

## Theoretical background 2.1

### :Introduction 2.1.1

The design of a nuclear medicine department should take account of several issues including radiationProtection, air .quality and infection control

It is important to consult with the RPA, the radio

,pharmacist,Medical physicist

The infections control officer and the radiologist or nuclear

.(medicine physician throughoutthe design phase (NHS, 2001

Where no radio pharmacist is available, the advice of a pharmacist should

.Be sought

## :Location and access nuclear medicine facility 2.1.2

A nuclear medicine facility must deal with all the problems of

receiving, storing, and handling, injectingMeasuring and imaging,

.and waste disposal for radioactive materials in a hospital setting

In determining location, ease of access for delivery of radioactive

.material and removal of waste must beconsidered

These activities may take place out of hours, so design and

.operational considerations are Involved

Direct egress for patients without going through the busy public

.areas of the hospital is desirablebut not always possible

The requirements for appropriate access for cleaning staff should

.(also be considered at the design stage.(Ireland June 2009

Ideally all the hospital's activities involving radioactive material should be centralized into one location toavoid transport of radioactive materials between units.Exceptions to this include some laboratories withinThe Pathology Service andsome research laboratories, some clinical areas such as Endocrinologyor Hematology may also use radioactive materials but, as far as possible, thehandling of larger amounts ofRadioactivity should be .centralized

.(Ireland June 2009)

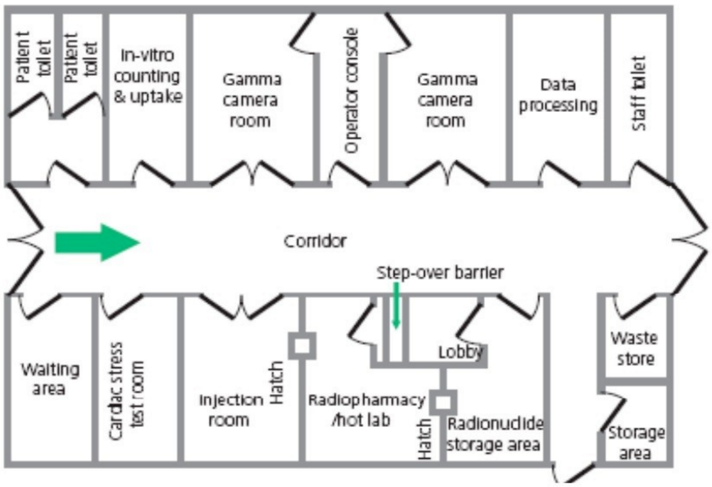



**Figure (2.1): Apossible layout of a nuclear medicine .department**

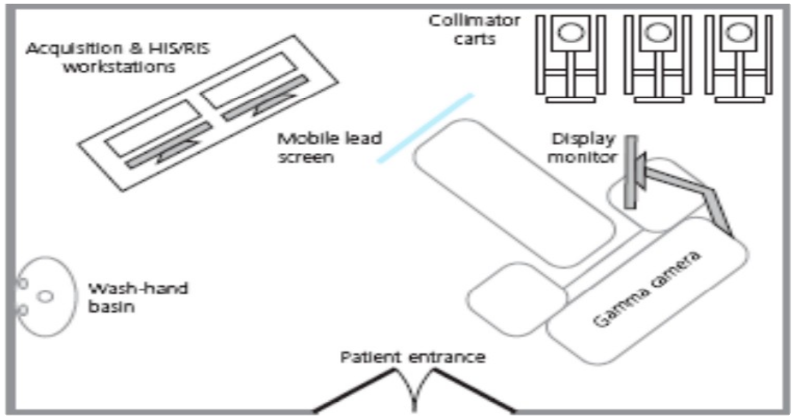



Figure (2.2): A possible layout of equipment in .gamma room

## 2.1.3Nuclear :medicine facilities

### :Scanning room 2.1.3.1

A nuclear medicine imaging unit will have one or more scanning rooms. The scanning room will house theGamma camera and the .operator console

The size of the room should be sufficient to accommodate theParticular
Type of scanner envisaged and allow for patient trolley access and collimator exchange (typically35-40m) Scanners with removable tables will need additional space for this facility.(Ireland June .(2009

## :Patient injection room 2.1.3.2

The patient injection area should be adjacent to the radio pharmacy and should be sized to accommodateone or two bays for ambulatory patients. At least one of the bays should be able to .accommodate wheelchairor trolley patients

Within the room, space should be provided for storage of consumables, shielded sharpsand general waste bins, and an instrument trolley; a wash hand basin with elbow or sensor .operated taps isAlso required

Some level of shielding is likely to be required in this area. The .RPA must advise accordingly but1mm lead is often adequate

The walls should be clearly marked to indicate the level of shielding provided

Access to the area should be via a signed and shielded .door

## :Waiting area 2.1.3.3

Patient waiting areas are required within the nuclear medicine department. Some departments segregatePatients pre-and post-administration of radioactive materials. Advice should be sought from the .RPA as towhether this is required

If a significant pediatric workload is envisaged, consideration should be given to a

Separate waiting area for children. Shielding requirements for the waiting area will depend on location andmust be determined by the RPA. Typically, 1-2 mm

Lead equivalence is normally adequate. This also appliesto any external

.(Windows included in the area. (Ireland June 2009

## Facilities:WC:2.1.3.4

WCs for use by nuclear medicine patients only should be provided within the department close to theWaiting area. The shielding requirements (if any) for this toilet area must be determined by the RPA. SignsLimiting access to other

Persons should be prominently placed on the doors, as these

.toilets are likely to becontaminated

### Reception /office/reporting and consultation 2.1.3.5

### :facilities

Office, reception, reporting or consultation facilities provided within the nuclear medicine department mustcomply with the design dose constraint of 0.3 mSv

.Per year

This may be achieved by a combination of sizeShielding and

.location

### :The lobby/changing area 2.1.3.6

A separate gowning/lobby leading to the hot lab/radio pharmacy is required (EANM, 2007). The lobby will beused by staff to

,change into aseptic clothing

And will therefore need appropriate signage and an indicationof

.when it is occupied

Shelving is required to store the appropriate aseptic clothing and a shielded bin should be available for usedand possibly .contaminated, clothing

A permanent barrier/demarcation must clearly identify the .(entrance to the “clean” area. (Ireland June 2009

### Hot lab and radio pharmacy 2.1.3.7:

The hot lab accommodates the production functions of the radio pharmacy area and for a single workstationshould not be less ,than 10 $m^2$ in area a hot lab of

Approximately 20 $m^2$ should comfortably facilitate twoCabinets or .isolators

Area for storage, preparation and dispensing of .radiopharmaceuticals

It must be secured and provided with adequate shielding. The amount of shielding is determined by a health physicist or radiation safety officer (RSO), depending upon the anticipated .usage of specific radioisotopes

## :Radionuclide storage area 2.1.3.8

A storage area is required for sealed and unsealed radioactive materials that will be used in the radio pharmacyand should be

.located adjacent to it

It may also serve as a central store for much, but not all, of the

Radioactive material used in the hospital. Typical dimensions for the storage room might be of the order of 10m$^2$an appropriately worded warning signshould be

Prominently displayed on the door and provision for control of

.access should be made

The shielding requirements for this area must be determined by the RPA and will depend on the level of theLocal shielding of each

.(source or subgroup of sources. (Ireland June 2009

## :Nuclear medicine Guide 2.1.4

The nuclear medicine design guide was developed as to assist contracting officer's medical center staff, and Architects, and planners with the design, and construction of nuclear medicine .facilities

It is not intended to be project specific, but rather provide an overview with respect to design and construction of nuclear .medicine facilities

Guide plates for various rooms within nuclear medicine are included to illustrate typical VA furniture, equipment, and .personal space needs

They are not project specific as it is not possible to foresee future .requirements

The project specific space program is the basic of design for an .individual project

It is important to note that the guide plates are intended as a .generic graphic representation only

Equipment manufactures should be consulted for actual dimensions, utilities, shielding, and other requirements as they relate to specified equipment, use of this design guide dose not supersede the project architects, and engineer's responsibilities to develop complete and accurate design that meets the user's needs and complies with appropriate code requirement.(Ireland .(June 2009

### :Definitions 2.1.5

#### :Diagnostic Room 2.1.5.1

Designated room containing diagnostic equipment performing patient procedures such as Nuclear Medicine, Bone Densitometry, .and PET/CT

It may also be referred to as Scanning Room, Procedure Room, or .Gantry Room

#### :”Hot ” 2.1.5.2

A colloquial term used to describe the presence of measurable radioactivity. In addition to the nature of the radioactive material itself, the distance from the radioisotope and the time of exposure .are important safety considerations

To keep exposure “as low as reasonably achievable” (ALARA), special waiting / holding areas, toilets and other support spaces may be designed for patients who have received a radioactive substance, depending upon factors including the specific . radiopharmaceutical used

## :2.1.5.3Nuclear Imaging

Method of producing images using gamma or scintillation cameras that detect radiation from different parts of a patient’s body after administration of a radioactive tracer material. Since physiologic / pathophysiologic processes are being monitored / measured, the patient must remain under the gamma camera for periods of time that vary from 20 to 90 minutes and may return for delayed images later in the same day or several days later. Modalities include Planar and Single Photon Emission Computed Tomography (SPECT) imaging, Positron Emission Tomography (PET), Fusion Imaging and Coincidence Detection imaging.(April .(2008

### :Patient Dose Administration 2.1.5.4

The process of metabolizing delivered radiopharmaceutical agents .in order to image the targeted metabolic function

Patient Dose Administration may require minutes, or even hours, before the imaging process can accurately capture the desired .results

Patient Dose Administration periods will be dependent upon the radiopharmaceutical utilized and the metabolic rate of the .tissues / organs targeted

### Picture Archiving and Communication System 2.1.5.5 :((PACS

The digital capture, transfer and storage of diagnostic images. A PACS system consists of workstations for interpretation, image/data producing modalities, a web server for distribution, printers for file records, image servers for information transfer and holding, and an archive of off-line information. A computer .network is needed to support each of these devices

## :(Positron Emission Tomography (PET 2.1.5.6

Positron Emission Tomography, also called PET imaging or a PET scan, is a diagnostic examination that involves the acquisition of physiologic images based on the annihilation radiation of positron-emitting radioisotopes administered to patients. Positrons are tiny particles emitted from a radioactive substance .administered to the patient

The subsequent images of the human body developed with this .(technique are used to evaluate a variety of diseases.(April 2008

## :PET/CT (Combined) Imaging 2.1.5.7

In one examination, a PET/CT scanner combines two state of the art imaging modalities and merges PET and CT images together. By monitoring the body’s metabolism, PET provides information of cell activity whether a growth within the body is cancerous or not. CT simultaneously provides detailed anatomic information about .the location, size, and shape of various lesions and tissue

.(April 2008)

## :Radio bioassay 2.1.5.8

This process utilizes specimens such as blood, urine, feces, spinal fluid, biopsies, etc., that are received and /or collected from patients, evaluated, and measured. Radioactive materials are incorporated in vivo or in vitro and determinations of body functions made. Specimen receiving, holding, preparation, examination, interpretation, consultation, record distribution, storage and retrieval occur in areas separate from the clinical .imaging function

## :2.1.5.9Radiopharmaceutical

Radiopharmaceutical: Term to describe radioactive agents .administered to a patient

Different agents have an affinity for the varying physiologic .processes of the body

These radioactive substances employed for diagnostic testing / imaging typically have very low doses of radioactivity, enabling patients to be treated on an outpatient basis with minimal .(restrictions following the exam.(April 2008

### :Scintillation or Gamma Camera 2.1.5.10

Nuclear imaging camera consists of a collection crystal (head) and magnifiers that create images of a target physiologic process from the radiation being emitted from a patient following the .administration of a radioactive uptake material

### Single Photon Emission Computed 2.1.5.11 :(Tomography (SPECT

Diagnostic imaging modality that usually employs a rotating collection crystal (head) and magnifiers to create three dimensional images of the distribution of single photon emissions .from the body

The images of the varying dimensional relationships are computer generated resulting in improved resolution of target .(organs / processes.(April 2008

## Room construction stander for nuclear 2.1.6 :medicine

Floors in offices, conference rooms and waiting areas should be .carpet with a 4inch high resilient

Floors in toilet rooms should be ceramic tile with a ceramic tile .base

Floors in imaging units, radio bioassay units and radio pharmacy .should have welded seam sheet

Flooring with an integral base, Floors in exam rooms and most other spaces should be vinyl Composition tile with a 4-inch high .resilient base

Treatment rooms and other spaces where higher doses of radiation or longer lived isotopes will be administered should be .of welded Seam sheet construction

Floor assemblies enclosing Nuclear Medicine rooms that require radiation shielding must have the shielding engineered by an .appropriately certified Health Physicist

Refer to H-18- 03 VA Construction Standard 64-1, X-Ray Radiation .shielding and Special Control Room Requirements

Construction documents will require written certification by a .registered Health Physicist

.Figure (2.3): A Room Floor in nuclear medicine

Ceiling height should be a minimum of 3meters, and should be .primarily lay-in acoustic ceiling tile

Certain areas, such as procedure Rooms and treatment rooms should have lay-in acoustic ceiling tile with a washable sprayed .Plastic finish

Coordinate the ceiling height requirements with the equipment .manufacturer

Pathways above ceilings for cable assemblies should be provided .for specific equipment type

Ceiling assemblies enclosing Nuclear Medicine rooms that require radiation shielding must have the shielding engineered by an .(appropriately certified Health Physicist. (April 2008

Refer to H-18- 03 VA Construction Standard 64-1, X-Ray Radiation .shielding and Special Control Room requirement

Construction documents will require written certification by a .registered Health Physicist

Wall and corner guards should be used in corridors and all other .areas where damage from Cart and stretcher traffic is anticipated

### :Interior Doors and Hardware 2.1.6.1

Interior doors should be 1 ¾ inch thick solid core flush panel wood .doors or hollow metal Doors in hollow metal frames

Door jambs, except in rooms with radiation shielding, should from the floor to facilitate mopping, Doors in wall assemblies that require shielding must be rated to provide the same shielding .Level as that in adjacent partitions

Hollow metal doors should be used where high impact is a .concern and where fire rated doors are required

Kick / mop plates should generally be applied to both sides of the .doors

.Handicapped accessible hardware should be used throughout

Doors leading to radionuclide receiving and storage area and radio pharmacy are required to be steel security doors that may .in some areas need to have proper lead shielding

Refer to VA Handbook PG-18-14, Room Finishes, Door and .Hardware Schedule, for additional information

## :Shielding 2.1.6.2

Radiation shielding is often necessary to protect adjacent occupancies, Give proper consideration to the weight of shielded .partitions, doors, ceilings and floors

In some instances, Structural building materials may provide adequate levels of radiation shielding in specific directions and .may not require additional layers of supplemental shielding

Floor depressions And / or door jamb reinforcement are .sometimes necessary

.(April 2008)

## Single-photon Emissioncomputedtomography 2.1.7 :((SPECT, or less commonly, SPET

Is a nuclear medicine tomographic imaging technique using gamma rays it is very similar to conventional nuclear medicine planar imaging using a gamma camera, However, it is .able to provide true 3D information

This information is typically presented as cross-sectional slices through the patient, but can be freely reformatted or manipulated .as require

The technique requires delivery of a gamma emitting radioisotope (a radionuclide) into the patient, normally .through injection into the bloodstream

On occasion, the radioisotope is a simple soluble dissolved ion,

.(such as a radioisotope of gallium (III

Most of the time, though, a marker radioisotope is attached to a specific ligand to create a radiology, whose properties bind it to certain types of tissues. This marriage allows the combination of ligand and radiopharmaceutical to be carried and bound to a place of interest in the body, where the ligand concentration is

.(seen by a gamma camera.(www.heart

**Figure (2.4):A Siemens brand SPECT scanner, consisting of .two gamma cameras**

## :Principle 2.1.7.1

Instead of just "taking a picture" of anatomical structures, a SPECT scan monitors level of biological activity at each place in the 3-D region analyzed. Emissions from the radionuclide indicate amounts of blood flow in the capillaries of the imaged regions. In the same way that a plain X-ray is a 2-dimensional (2-D) view of a 3-dimensional structure, the image obtained by a gamma camera is a 2-D view of 3-D distribution of a radionuclide.

SPECT imaging is performed by using a gamma camera to acquire multiple 2-D images (Also called projections), from multiple angles.

A computer is then used to apply a tomographic reconstruction algorithm to the multiple projections, yielding a 3-D data set.

This data set may then be manipulated to show thin slices along any chosen axis of the body, similar to those obtained from other tomographic techniques, such as magnetic resonance imaging (MRI), X-ray computed tomography (X-ray CT), and positron emission tomography(PET).(www.heart).

SPECT is similar to PET in its use of radioactive tracer material and detection of gamma rays. In contrast with PET, however, the tracers used in SPECT emit gamma radiation that is measured directly, whereas PET tracers emit positrons that annihilate with electrons up to a few millimeters away, causing two gamma

.photons to be emitted in opposite directions

A PET scanner detects these emissions "coincident" in time, which provides more radiation event localization information and, thus, higher spatial resolution images than SPECT (which has about 1 cm resolution). SPECT scans, however, are significantly less expensive than PET scans, in part because they are able to

.use longer-lived more easily obtained radioisotopes than PET

Because SPECT acquisition is very similar to planar gamma camera imaging, the same radiopharmaceuticals may be used. If a patient is examined in another type of nuclear medicine scan, but the images are non-diagnostic, it may be possible to proceed straight to SPECT by moving the patient to a SPECT instrument, or even by simply reconfiguring the camera for SPECT image

.(acquisition while the patient remains on the table.(www.heart

**Figure (2.5): SPECT machine performing a total body bone .scan**

The patient lies on a table that slides through the machine, while .a pair of gamma cameras rotates around her

To acquire SPECT images, the gamma camera is rotated around the patient. Projections are acquired at defined points during the rotation, typically every 3–6 degrees. In most cases, a full 360-.degree rotation is used to obtain an optimal reconstruction

The time taken to obtain each projection is also variable, but 15–20 seconds is typical. This gives a total scan time of 15–20 .minutes

Variable, but 15–20 seconds is typical. This gives a total scan time .of 15–20 minutes

Multi-headed gamma cameras can provide accelerated .acquisition

For example, a dual-headed camera can be used with heads spaced 180 degrees apart, allowing two projections to be acquired simultaneously, with each head requiring 180 degrees of .(rotation.(www.heart

Triple-head cameras with 120-degree spacing are also usedCardiac gated acquisitions are possible with SPECT, just as with planar imaging techniques such as Multi Gated Acquisition .(Scan (MUGA

Triggered by electrocardiogram (EKG) to obtain differential information about the heart in various parts of its cycle, gated myocardial SPECT can be used to obtain quantitative information about myocardial perfusion, thickness, and contractility of the myocardium during various parts of the cardiac cycle, and also to allow calculation of left ventricular ejection fraction, stroke

.volume, and cardiac output

### :APPLICATION 2.1.7.2

SPECT can be used to complement any gamma imaging study, where a true 3D representation can be helpful, e.g., tumor imaging, infection (leukocyte) imaging, thyroid imaging or bone scintigraphy Because SPECT permits accurate localization in 3D space, it can be used to provide information about localized function in internal organs, such as functional cardiac or brain

.(imaging.(www.heart

## :Gamma camera 2.1.8

A gamma camera, also called a scintillation camera or Anger camera, is a device used to image gamma radiation emitting

.radioisotopes, a technique known as scintigraphy

The applications of scintigraphy include early drug development and nuclear medical imaging to view and analyses images of the human body or the distribution of medically injected, inhaled, or .ingested radionuclides emitting Gamma rays

### :Construction 2.1.8.1

A gamma camera consists of one or more flat crystal planes (or detectors) optically coupled to an array of in an assembly known .as a "head", mounted on a gantry

The gantry is connected to a computer system that both controls the operation of the camera as well as acquisition and storage of .acquired images

The construction of a gamma camera is sometimes known as a .compartmental radiation construction

The system accumulates events, or counts of gamma photons that are absorbed by the crystal in the .camera

Usually a large flat crystal of sodium iodide with thallium doping .in a light-sealed housing is used

The highly efficient capture method of this combination for detecting gamma rays was discovered in 1944 by Sir Samuel Curran whilst he was working on the Manhattan Project at .the University of California at Berkeley

Nobel prize-winning physicist Robert Hofstadter also worked on .(the technique in 1948.(http:\en .Wikipedia

The crystal scintillates in response to incident gamma radiation. When a gamma photon leaves the patient (who has been injected with radioactive), it knocks an electron loose from an iodine atom in the crystal, and a faint flash of light is produced when the .dislocated electron again finds a minimal energy state

The initial phenomenon of the excited electron is similar to the effect and (particularly with gamma rays) the Compton effect. .After the flash of light is produced, it is detected

Photomultiplier tubes (PMTs) behind the crystal detect the .fluorescent flashes (events) and a computer sums the counts

The computer reconstructs and displays a two dimensional image .of the relative spatial count density on a monitor

This reconstructed image reflects the distribution and relative concentration of radioactive tracer elements present in the organ .and tissues imaged

.(http:\en .Wikipedia)

**.Figure (2.6): An old Anger gamma Camera**

## :Radiation Protection 2.1.9

Because radiation can cause damage in living systems, international and

National organizations have been established to set guidelines for the safe

.Handling of radioactive materials

The International Committee on Radiological Protection (ICRP) and the National Councilon Radiation Protection and Measurement (NCRP) are two such organizations

They set guidelines for all radiation workers to follow in handling .radiations

The NRC adopts these recommendations into regulations for implementing

.Radiation protection programs in the U.S

At present, the 10CFR20 contains all major radiation protection .regulations applicable in the U.S

Since it is beyond the scope of this book to include the entire .10CFR20, only the relevant Highlights of it are presented here

### :ALARA Program 2.1.9.1

The dose limits are the upper limits for radiation exposure to .individuals

The NRC has instituted the ALARA (as low as reasonably achievable) concept to

Reduce radiation exposure to individuals The ALARA concept calls for a reasonable effort to maintain individual and collective doses .as low as possible

**:Principles of Radiation Protection 2.1.9.2**

Of the various types of radiation, the a particle is most damaging due to its

.Great charge and mass, followed by the b particle and the gray

Heavier particles have shorter ranges and therefore deposit more energy per unit path

Length in the absorber, causing more damage. These are called none penetrating

.(Radiations.(Copal B. Saha, PhD

On the other hand, g and x-rays have no charge and mass and

.therefore have a much longer range in matter

These electromagnetic radiations Are called penetrating

.radiations

Knowledge of the type and energy of Radiations is essential in

.understanding the principles of radiation protection

The cardinal principles of radiation protection from external

.sources are based on time, distance, shielding, and activity

**:Time 2.1.9.3**

The total radiation exposure to an individual is directly proportional to the

.Time the person is exposed to the radiation source

.The longer the exposure, the higher the radiation dose

Therefore, it is wise to spend no more time than necessary near .radiation sources

## :Distance 2.1.9.4

The intensity of a radiation source, and hence the radiation exposure, varies

.Inversely as the square of the distance

It is recommended that an individual remains as far away as .possible from the radiation source

Procedures and Radiation areas should be designed such that only minimum exposure takes

Place to individuals doing the procedures or staying in or near the .radiation areas

## :Shielding 2.1.9.5

Various high atomic number (Z) materials that absorb radiations .(can be used to provide radiation protection.(Copal B. Saha, PhD

Since the ranges of a and b particles are short in matter, the

.containers themselves act as shields for these radiations

However, gmma radiations are highly penetrating, and therefore highly absorbing Material must be used forShielding of g-emitting

,sources for economic reasons

Lead is most commonly the conceptof half value layer (HVL) ofan absorbingthe

Material for penetrating radiations is Important in It is defined as the thickness of shieldingdesign of shielding for radiation protection.That reduces the exposure from a radiation source by

.one half

Thus, an HVL of an absorber placed around a source of radiation with an exposure

.Rate of 100 mR/h will reduce the exposure rate to 50 mR/h

The HVL is dependent on both the energy of the radiation and the atomic Number of theAbsorbing material The HVL value is greater

.for high-energy Radiations andSmaller for high Z materials

### :Activity 2.1.9.6

It should be obvious that the radiation hazard increases with the

.intensity of the radioactive source

.The reader the source strength, the more the radiation exposure

Therefore, one should not work unnecessarily with high quantities

.(of radioactivity. (Copal B. Saha, PhD

## :previous studies 2-2

After viewing the open literature, especially the internet, and the researchers found few studies in the researcher's study field these :included

**Nadia M Sirag1* and Abdelrazek Hussein,** (2015) study by

DESIGN CONSIDERATIONS TO MINIMIZE STAFF DOSES IN NUCLEAR MEDICINE UNITS and they founded The aim of there was to achieve require to achieve the ALARA principle, to reduce the radiation exposure to workers in the field of the medicine and to minimize as not as possible the staff doses, such that become familiar with the types of sources used in diagnostic and radiation therapy. They also have to be aware of how the basic principles of defense in term of safety of sources and optimization are .applied to the design of diagnostic and radiation therapy facility

This paper document provides information for a recommended approach for meeting the requirements related to the site description and room design such that the design should maintain .(the doses As Low as Reasonably Achievable (ALARA

**HaleyCoolsaet1 and Cheri' O'Leary** (2015) studied the Effectiveness of using SPECT/CT to reduce operating room times in surgical parathyroid patients. They found that the time was not effective in locating parathyroid adenomas compared to the use of SPECT in regards to a decrease in the amount of time spent in surgery during Para thyroidectomy procedures. However, even though there was no significant difference in the mean surgical times, SPECT/CT is still the preferred acquisition method for .Surgeons

# CHAPTER THREE

# Materials and methods

## :Materials 3.1

.Measurement meter

.CONTAMAT FHT 111 M Thermo scientific

Survey Meter Invasion Model 451P Pressurized Certificate No: .SAEC/24/014

## :Methods of study 3.2

**Area of the study**: this study was performed at **3.2.1** .RICK and Alnilain nuclear medicine centers

**Duration of study:** the study duration was from **3.2.2** .December first to 29$^{th}$ of February, 2016

**Data collection:** Data were collected from text books, **3.2.3** .references, websites, and personal contact

**Data analysis**: Qualitative and Quantitative description, **3.2.4** statically methods that include arithmetic means, and standard deviation, and the data were processed using computer programs .including excel

.Figure (3.1): CONTAMAT FHT111M at Alnlain

.Figure (3.2): Survey Meter Invasion Model 451PRICK

# CHAPTER FOUR

# RESULTS

Survey used Invasion Model 451P and CONTAMAT FHT 111 M meter to measure the doses at nuclear medicine department environment (hot lab, gamma camera, waiting room, injection .(room

The results were shown in tables [from table (4.1) to table (4.10)], .[(and were summarized in figures [from fig (4.1) to Fig (4. 12

Table 4.1: Shows dimensions of Rooms measurement for .nuclear medicine department in RICK

| Standard/ $m^2$ | Area/ $m^2$ | Dimensions | | | Room |
|---|---|---|---|---|---|
| | | highs | Width | Length | |
| 35-40 | $77.3m^2$ | 2.97 | 4.34 | 6 | Imaging room |
| 10-15 | $17.4m^2$ | 2.24 | 3.93 | 2.63 | Control room |

| | | | | | |
|---|---|---|---|---|---|
| 6 | 20 | | 5 | 4 | Waiting area |
| 20 | 9 | | 3 | 3 | Hot lab |
| 10 | 18 | | 6 | 3 | Storage area |
| 1.75 | 192.6 | | 90 | 2.14 | Door |
| 90 | 36.12 | | 8.4 | 4.3 | Lead Window |
| 2.2 | 2.97 | | - | - | Wall thickness heights |
| 1.1 | 0.5 | | - | - | Door thickness |
| 3> | - | 2.97 | - | - | Ceiling high of the imaging room |

Table 4.2: Shows dimensions of Rooms measurement for nuclear medicine department At .Alnilaincenter

| Standard/ | Area/$m^2$ | Dimensions | Room |
|---|---|---|---|

| m² | | High | Width | Length | |
|---|---|---|---|---|---|
| 35-40 | 35.9 | 2.79 | 3.44 | 3.74 | Imaging room |
| 10-15 | 22.1 | 2.79 | 4.10 | 1.93 | Control room |
| 10 | 3.4 | - | 2 | 1.7 | Storage area |
| 6 | 18.4 | - | 4.73 | 3.9 | Waiting area |
| 20 | 4.6 | - | 2.1 | 2.21 | Hot lab |
| 1.75 | 185.6 | - | 82.5 | 2.25 | Door |
| 90 | 31 | - | 7.2 | 4.3 | Lead Window |
| 2.2 | 2.79 | - | - | - | Wall thickness heights |
| 1.1 | 0.5 | - | - | - | Door thickness |
| 3> | - | 2.79 | - | - | Ceiling high of the imaging room |

Table4.3: Shows the constructionsmaterials of different areas of SPECT Gamma Camera room in .RICK

| Material | area |
|---|---|
| .Concrete | Celling |
| .Concrete and ceramic | Wall |
| Concrete and chemical .resistant | Floor |
| Lead and hollow metal .doors in hollow frames | Door |
| .Lead glass | Window |

Table 4.4: Shows theconstructionsmaterialsdifferent areas of .SPECT Gamma Camera room at Alnilain center

| Material | Component |
|---|---|
| .Concrete | Celling |
| .Concert and ceramic | Wall |
| .Chemical resistant and ceramic | Floor |
| Lead and thickness solid core .panel wood door | Door |
| .Lead glass | Window |

Table 4.5: Shows doses in the presents of injected patients at .different areas in Alnilain center

| Corridor | Floor of I.R | Imaging room | Floor of W.A | Waiting area | Floor of IN.R | Table of IN.R | Injectio n room | Sink of H.L | Floor of H.L |
|---|---|---|---|---|---|---|---|---|---|
| 0.32 | 3.0 | 7.2 | 3.0 | 3.2 | 0.12 | 0.691 | 1.02 | 13.01 | 16.0 |
| 0.1 | 0.01 | 1.02 | 0.3 | 0.92 | 0.1 | 0.03 | 0.09 | 1.92 | 3.01 |
| 0.09 | 0.1 | 0.691 | 0.4 | 0.9 | 0.09 | 0.04 | 1.01 | 3.0 | 4.01 |
| 0.2 | 0.02 | 3.41 | 0.693 | 1.2 | 0.08 | 0.09 | 1.02 | 7.13 | 10.2 |
| 0.22 | 2.0 | 5.2 | 2.0 | 2.2 | 0.13 | 0.691 | 2.1 | 11.1 | 14.1 |
| 0.12 | 0.015 | 4.34 | 1.70 | 2.1 | 0.630 | 1.22 | 2.1 | 4.74 | 6.0 |
| 0.11 | 0.08 | 3.34 | 1.4 | 1.1 | 0.5 | 0.09 | 1.1 | 3.74 | 5.0 |
| 0.2 | 2.07 | 32 | 3.50 | 5.06 | 0.719 | 1.15 | 7.1 | 6.7 | 9.00 |
| 0.12 | 1.06 | 30 | 2.50 | 4.06 | 0.5 | 1.0 | 5.1 | 4.7 | 7.00 |
| 0.32 | 0.25 | 12 | 0.965 | 0.2 | 60.6 | 146 | 62.9 | 16.5 | 16 |
| 0.1 | 0.21 | 5 | 0.641 | 0.1 | 1.00 | 1.06 | 1.09 | 3.01 | 4.37 |
| 0.12 | 0.720 | 8.42 | 2.50 | 0.1 | 0.09 | 1.02 | 1.06 | 4.70 | 2.77 |
| 0.1 | 0.315 | 6.55 | 0.55 | 0.2 | 5.05 | 7.55 | 9.8 | 1.55 | 0.941 |
| 0.1 | 0.12 | 4.4 | 0.33 | 0.1 | 3.05 | 5.55 | 7.8 | 1.0 | 0.741 |
| 0.13 | 0.403 | 2.25 | 35.1 | 15.7 | 0.389 | 1.05 | 2.1 | 2.69 | 2.51 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0.14 | 1.2 | 20.8 | 1.25 | 2.4 | 0.01 | 1.1 | 2.0 | 1.02 | 0.31 |
| 0.5 | 3.84 | 1.90 | 20.2 | 13.6 | 7.17 | 9.77 | 10.7 | 22.6 | 18.1 |
| 0.811 | 0.695 | 1.02 | 16.4 | 3.58 | 6 | 8.08 | 14 | 9.38 | 8.35 |
| 0.6 | 1.07 | 22 | 0.390 | 0.335 | 4 | 6.06 | 12 | 3.2 | 6.08 |
| 0.9 | 0.425 | 1.09 | 0.735 | 0.7 | 13 | 15.5 | 30 | 12 | 15.1 |

Table 4.6: Shows mean ± SD for all variables in nuclear .medicine department RICK

| Mean+ SD | Variable |
|---|---|
| ±0.2 0.2 | Reception |
| 0.2 ± 0.1 | Corridor |
| 0.1 ± 0.1 | Office physics |
| 0.1 ± 0.2 | Corridor |
| 2.6 ± 1.5 | Waiting area |
| 1.6 ± 0.9 | Imaging room A |
| ±0.67 0.43 | Control area |
| 0.82 ± 0.92 | Imaging room B |
| 2.4 ± 2.9 | Hot lab |
| 3.3 ± 5.1 | Shielding |
| 6.7 ± 3.9 | Inside shielding |
| 0.8 ± 1.2 | Inside door |
| 2.2 ± 2.1 | Waste hot |

| | |
|---|---|
| Dose calibrator | 1.1 ± 1.4 |
| Storage door | 1.1 ± 1.2 |
| Middle storage | 1.2 ± 1.4 |
| Tank 1 | 0.4 ± 3.1 |
| Tank 2 | 1.1 ± 3.9 |

Table 4.7: Shows mean ± SD for all variables in Alnilain of .nuclear medicine department

| Variable | Mean ± SD |
|---|---|
| Floor of Hot lab | 5.7 ± 7.5 |
| Sink of Hot lab | 5.8 ± 6.7 |
| Injection room | 14.6 ± 8.7 |
| Table of Injection room | 32.2 ± 10.4 |
| Floor of injection room | 13.5 ± 5.2 |
| Waiting area | 1.7 ± 2.9 |
| Floor of waiting area | 8.9 ± 4.7 |
| Imaging room | 4.3 ± 8.6 |
| Floor of imaging room | 0.9±1.1 |
| Corridor | 0.2 ± 0.3 |

**:Assumed radiation received at two departments**

If we assume that the workers spent in these places an average of 6 days \week, 42 weeks /year, the dose received per year could be assumed as follows:

Dose per hourx2 hour per day x6 days per week x42week per year

**Gamma camera:**

20 days = 0.9 msv.

1day = 0.9/20= 0.045 msv.

Annual dose = 0.045x 2x6x42=22.68 msv/y.

**Hot lab:**

20 days = 2.9 msv.

1day = 2.9/20= 0.145msv.

Annual dose = 0.145x2x6x42=73.08 msv/y.

**Injection room:**

20 days = 1.4 msv.

1day = 1.4/20= 0.07 msv.

Annual dose = 0.07x2x6x42=35.28 msv/y.

.Table 4.8: shows annual dose received per year at RICK

| Standard | Average dose \year | Room |
|---|---|---|
| | 0.045x6x42=22.68msv\year | Gamma camera |
| | 0.145x2x6x42=73.08msv\year | Hot lab |
| 50msv\year | 0.07x2x6x42=35.28msv\year | Injection room |

If we assume that the worker spend in these place an average of :3day\week-21week\year the occupancy assumption is

Dose per hourx2 hour per day x3 days per weeks x21 weeks per year

:**Gamma camera**

.days=6.0 msv 20

1day reading =0.6/20=0.3msv

.Annual dose = 0. 3x2x3x21=37.8msv/y

**:Hot lab**

.days = 8.7 msv 20

.1day reading = 8.7/20= 0.435 msv

.Annual dose= 0.435x2x3x21=54.81msv/y

**:Injection room**

.days = 7.0 msv 20

.1day=7.0/20=0.35msv

.Annual dose= 0.35x2x3x21=44.1msv/y

.Table 4.9: shows annual dose at Alnilain center

| Standard | Average dose \year | Room |
|---|---|---|
| 50msv\year | .3x2x3x21=37.8 msv/y .0 | Imaging room |
| | .0.435x2x3x21=54.81msv/y | Hot lab |
| | .0.35x2x3x21=44.1msv/y = | Injection room |

.Figure (4.1): imaging room and injection room doses at RICK

.Figure (4.2): imaging room and waiting room doses at RICK

.Figure (4.3): imaging room and hot lab doses at RICK

.Figure (4.4):  Hot lab and waiting room doses at RICK

.Figure (4.5): Hot lab and imaging room doses at RICK

.Figure (4.6): Hot lab and injection room doses at RICK

.Figure (4.7): imaging room and injection room doses at Alnilain

.Figure (4.8): imaging room and waiting room doses at Alnilain

.Figure (4.9): imaging room and hot labdoses at Alnilain

.Figure (4.10):  hot lab and waiting room doses at Alnilain

.Figure (4.11): hot lab and injection room doses at Alnilain

.Figure (4.12): Hot lab and injection room doses at Alnilain

## :Discussion 2 .4

This study was conducted at the nuclear medicine departments in Khartoum state and covered two nuclear medicine centers, namely RICK and Alnilain centers. The radiation doses in the two centers were measured at different areas including injected patients waiting area, hot lab, injection room and gamma camera .room

Tables (4.1) and (4.2) showed dimensions of the rooms of all nuclear medicine department. According to these results, the dimensions of the rooms at RICK are bigger than Alnilain center rooms. These because the gamma camera in RICK are bigger (dual head machine), and the number of patients is greater. The .dimensions of both centers are adequate for the time being

Tables (4.3) and (4.4): Showedthe construction materials of different areas of SPECT Gamma Camera room .The results showed that the construction materials of both centers were .similar although there were differences of doors material

Tables (4-5) and (4-6) Showed results of survey meter used to measure the doses of the rooms of the two nuclear medicine departments, during the lifetime of the generators. The results showed that the dose at the hot lab during the first day was higher than the other days on which the doses decreased .gradually

As for Alnilain center, the first day dose was the highest dose and the doses decreased gradually at the other days. There were many factors which influence the quantity of the doses namely : the generator activity , the number of injected patients, the presence of other sources in the hot lab and the type of study .((dynamic or static

Tables (4.7) and (4.8) showed the mean ± SD variables, according to which the doses at RICK were lower than the doses received at .Alnilain center

Themean dose of the hot lab were (2.9), injection room (1.4), imaging room (0.9) at RICK. The mean dose of the hot labat Alnilain center were (7.5), injection room (5.7), imaging room .((0.9

Tables (4.9) and (4.10) showed the assumed annual doses at the .injection room, imaging room and hot lab

The hot lab showed the highest dose followed by, the injection room, and the imaging room respectively because the hot lab is the Place for patient's doses preparation ($TC^{99m}$, $I^{131}$…etc.) .The injection room's high dose could be attributed to the number of injected patients, and it is part of the hot lab. As for the imaging room, the dose was low because there was no radiation source .and only the patients were the source of radiation

All the doses were below the national and international standards (50msv\year for workers), and the results agreed with the previous study done by Nadia M Sirag1* and AbdElrazekZ .Hussein

# CHAPTER FIVE

# Conclusion, Recommendations and Reference

## :Conclusion 5.1

This study was done to evaluatethe Room Design of SPECT Gamma Camera in Alnailne and RICK Nuclear Medicine Centers. Many measurements of the imaging room, waiting room, hot lab, and the injection room were done and their results were summarized in tables (4.5) and (4.6) and figure (4.1) to (4.12).The doses received at RICK seemed to be lower than those received at .Alnilain center

It was found that the assumed annual doses received at the injected patients rooms in RICK and Alnilain centers, using survey meter Invasion Model 451P Pressurized and CONTAMAT FHT 111 M, were lower below than the national and international standards, although it was too difficult to know the real annual doses received by workers at the two centers under the study without the use of personal dose meters such as the TLD. This means that the worker of two centers need to wear these devices .all the time in order to have the real doses received by them

## :Recommendations 5.2

It is recommended that an individual remains as far away as .possible from the radiation source

.The lead is the best material for gamma ray and x-rays shielding

Concrete material should always be used when building nuclear medicine departments to prevent the leakage of radiation outside .the building

Encouraging the cooperation between the relevant regulatory bodies in Sudan and the IAEA to provide technical support in terms of training courses and the provision of personal dosimeters .for nuclear medicinecenters

More than one nurse in the nuclear medicine department should be available so that they can share the radiation doses received .by hand and whole body

Routine survey to the nuclear medicine department, especially .the hot lab, should be done

To decrease the workers radiation exposure and contamination, .decontamination kits should always be kept and fully stock

## :REFRENCES

_**F**reek J Beekman and Brendan Vastenhouw(2004) Physics in .Medicine and Biology, Volume 49, Number 19

.IOP Publishing Ltd

**I**nternational journal engineering reached and science and technology ISSN 2319-5991 www.ijerst.com Vol. 4, No. 1, February .2015 © 2015 IJERST

.**H**Coolsaet - Journal of Nuclear Medicine, 2015 - Soc Nuclear Med

**A** Code of Practice on the design diagnostic medical facilities using ionizing radiation issued by the Radiological Protection .Institute of Ireland June 2009

.**V**A design Guide nuclear medicine \April 2008

**G**opal B. Saha, (2010) Fundamentals of Nuclear Pharmacy, Sixth .Edition, the Cleveland Clinic Foundation Cleveland, OH 44195

## :Web sites


**http: //** en .Wikipedia .org \wiki **G**amma Camera from-**1** Wikipedia .the free encyclopedia http \Gamma Camera accessed .20th 2016

**http: // w**ww.heart .org\condition\Attack \SPECT\CT.SPECT CT-**2** .-ucm-446358, accessed on January 17th 2016

**http:** // **w**ww.radiology info.org\en\info. Cfm pg. =gen nuclear-**3** .(general nuclear medicine, accessed on January 15th 2016

## :Appendix

.(shows doses in the presence of injected patients at different areas in RICK (µSv/h

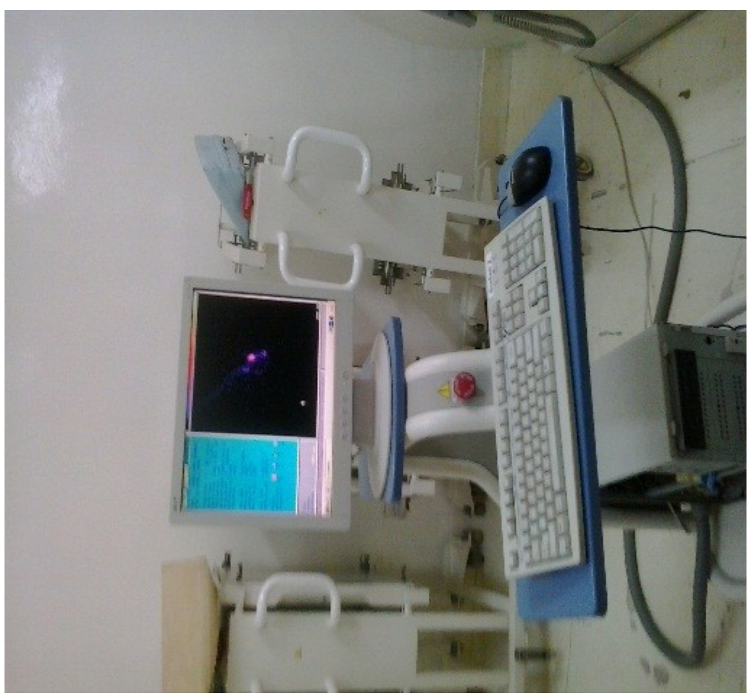
| Tank 2 | Tank 1 | Mild storage | Storage door | Dose calibrator | Wastes bin | Inside door | Inside shielding | Shielding | Hot lab | Imaging room B | Control room | Imaging room A | Waiting area | corridor | physics Office | Corridor | Reception |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.9 | 2.6 | 1.9 | 2.2 | 1.1 | 0.01 | 0.02 | 0.55 | 0.31 | 0.01 | 0.07 | 0.72 | 0.85 | 0.08 | 0.06 | 0.09 | 0.03 | 0.1 |
| 2.9 | 2.7 | 1.6 | 2.3 | 2.00 | 0.1 | 0.92 | 4.9 | 0.37 | 0.42 | 0.08 | 0.71 | 1.01 | 0.07 | 0.08 | 0.07 | 0.09 | 0.08 |
| **3.0** | **2.1** | 1.2 | 1.3 | 2.1 | 0.26 | 0.72 | 0.29 | 0.2 | 0.26 | 0.02 | 0.42 | 0.48 | 0.09 | 0.04 | 0.01 | 0.03 | 0.08 |
| **2.9** | **2.2** | 1.9 | 1.8 | 0.3 | 1.9 | 1.9 | 3.5 | 10.2 | 0.7 | 0.01 | 0.03 | 0.09 | 0.08 | 0.05 | 0.09 | 0.09 | 0.08 |
| **3.2** | **2.3** | 1.5 | 1.8 | 0.01 | 0.09 | 0.7 | 1.7 | 4.5 | 3.6 | 0.07 | 0.12 | 1.77 | 0.09 | 0.07 | 0.04 | 0.07 | 0.02 |
| **3.6** | **3.4** | 1.6 | 0.5 | 4.1 | 1.9 | 1.9 | 28 | 11.9 | 1.9 | 0.05 | 0.6 | 1.84 | 3.7 | 0.2 | 0.06 | 0.08 | 0.03 |
| **3.9** | **3.4** | 1.5 | 2.4 | 2.1 | 2.1 | 0.7 | 11.3 | 9.1 | 9.00 | 0.5 | 2.4 | 7.0 | 10.4 | 0.3 | 0.09 | 0.8 | 0.5 |
| 3.3 | 3.4 | 1.6 | 2.3 | 2.6 | 0.7 | 0.6 | 10.3 | 9.00 | 9.1 | 0.5 | 2.0 | 1.2 | 6.5 | 0.4 | 0.07 | 0.4 | 0.02 |
| 6.1 | 3.1 | 5.4 | 0.4 | 3.1 | 1.1 | 0.8 | 1.9 | 8.6 | 3.5 | 1.39 | 0.07 | 2.1 | 1.8 | 0.1 | 0.09 | 0.03 | 0.07 |
| 5.1 | 3.0 | 1.7 | 0.3 | 0.6 | 0.8 | 1.3 | 0.4 | 4.1 | 2.1 | 1.4 | 0.03 | 0.01 | 0.3 | 0.13 | 0.06 | 0.10 | 0.06 |
| 4.1 | 3.2 | 1.9 | 0.2 | 0.9 | 0.7 | 2.5 | 0.38 | 7.1 | 4.1 | 1.2 | 0.05 | 0.01 | 0.6 | 0.2 | 0.06 | 0.05 | 0.07 |
| 5.0 | 3.3 | 2.0 | 0.4 | 0.9 | 0.65 | 1.4 | 0.24 | 4 | 3.2 | 2.7 | 0.3 | 0.07 | 0.6 | 0.2 | 0.2 | 0.04 | 0.03 |
| 6.0 | 3.2 | 1.4 | 0.3 | 0.7 | 5.7 | 1.1 | 4.5 | 4.8 | 3.7 | 1.19 | 0.3 | 0.04 | 0.64 | 0.39 | 0.06 | 0.07 | 0.09 |
| 3.1 | 3.4 | 0.3 | 0.1 | 0.5 | 4.5 | 2.1 | 0.23 | 3.5 | 2.4 | 2.0 | 0.07 | 0.05 | 1.1 | 0.26 | 0.02 | 0.05 | 0.5 |
| 6.0 | 3.0 | 0.3 | 4.1 | 3.1 | 1.1 | 0.5 | 1.7 | 6.5 | 2.2 | 1.3 | 0.06 | 1.1 | 1.8 | 0.1 | 0.07 | 0.02 | 0.06 |
| 3.8 | 3.5 | 0.4 | 1.5 | 0.7 | 1.2 | 0.3 | 0.3 | 4.1 | 2.1 | 1.3 | 0.02 | 0.01 | 0.2 | 0.1 | 0.05 | 0.12 | 0.06 |
| 3.6 | 3.3 | 0.3 | 0.3 | 0.6 | 5.4 | 2.1 | 0.21 | 3.1 | 2.5 | 2.2 | 0.05 | 0.03 | 1.0 | 0.1 | 0.01 | 0.04 | 0.5 |
| 3.2 | 3.4 | 0.2 | 1.3 | 0.6 | 5.7 | 1.1 | 4.2 | 4.3 | 3.0 | 1.19 | 0.2 | 0.03 | 0.53 | 0.21 | 0.07 | 0.05 | 0.09 |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.9 | 3.3 | 0.2 | 0.6 | 0.52 | 1.5 | 0.23 | 3 | 3.2 | 2.7 | 0.3 | 0.02 | 0.06 | 0.5 | 0.1 | 0.21 | 0.04 | 0.03 |

## :Data collection at Alnilain

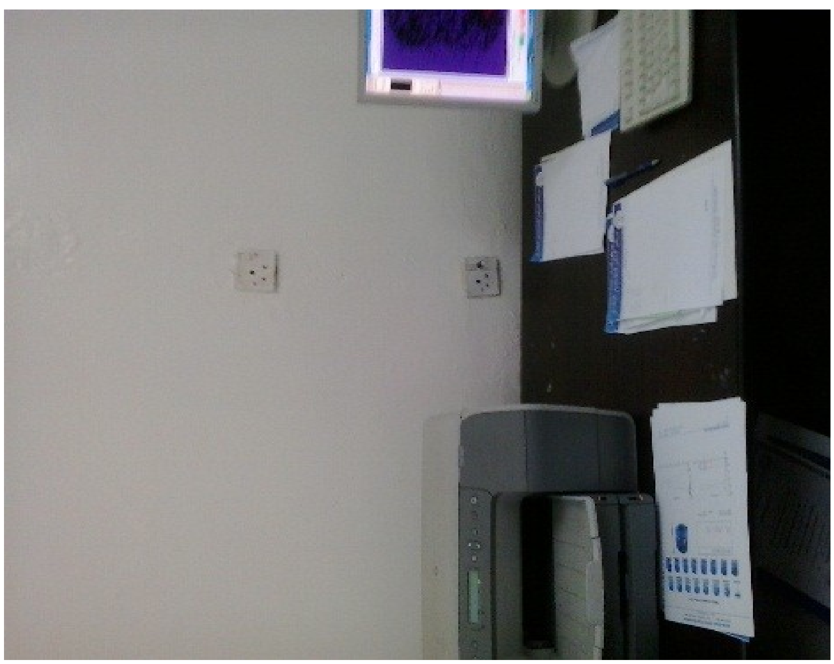
| Corridor | Floor of I.R | Imaging room | Floor of W.A | Waiting area | Floor of IN.R | Table of IN.R | Injection room | Sink of H.L | Floor of H.l |
|---|---|---|---|---|---|---|---|---|---|

.Figure (5.1): The imaging room at RICK



.Figure (5.2): Control room at RICK

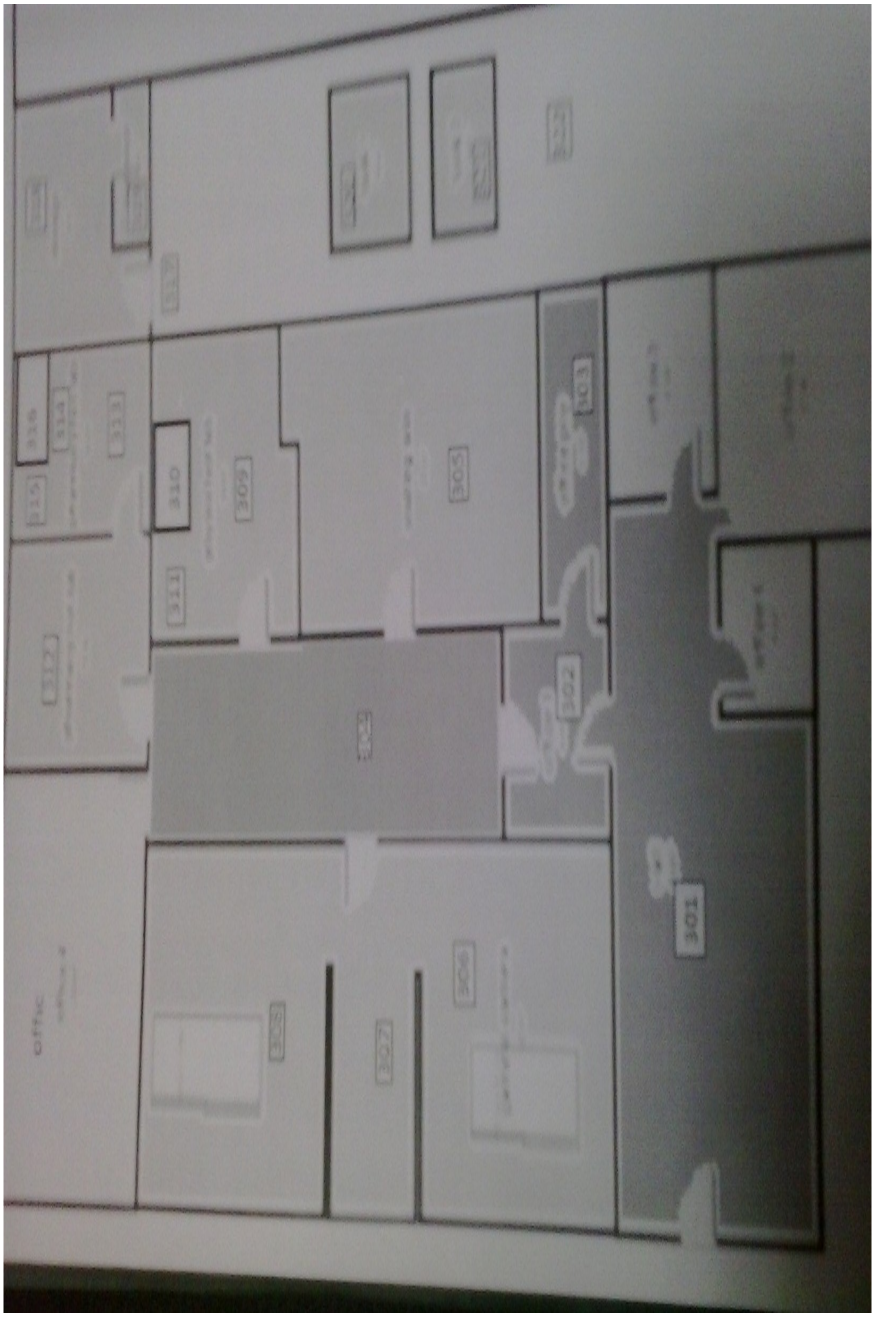
.Figure (5.3): The imaging room atAlnilain



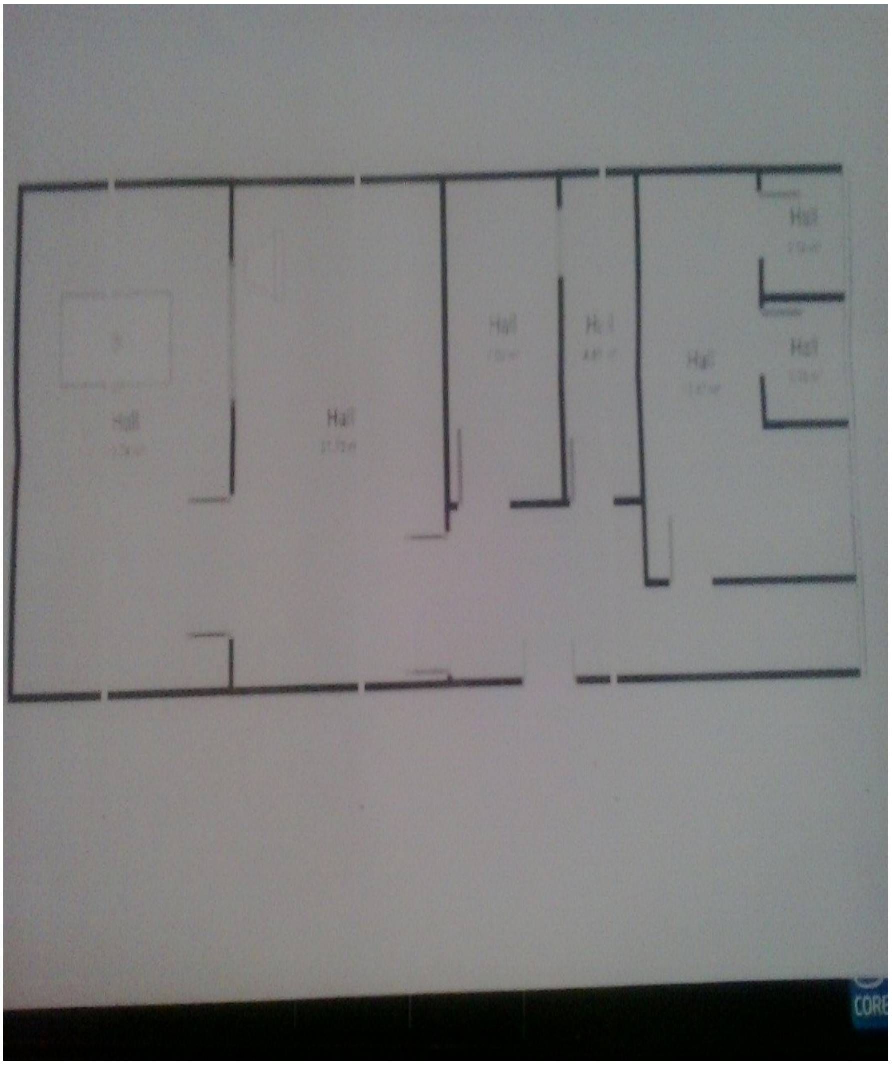
.Figure (5.4):  The Control room at Alnilain

.Figure (5.5): The door of Alnilain Center


.Figure (5.6): The door of RICK Center




.Figure (5.5): The layout of nuclear medicine department at RICK



..Figure (5.6): The layout of nuclear medicine department